

The Effect of Music Tempo on Physical Activity

Undergraduate Research Thesis

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by

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### Abstract

Music influences the way we move, whether we are dancing, running, or tapping our fingers. Research has indicated that music tempo influences gross and fine motor movements. Does music rate also have a robust effect on fine motor tasks such as finger tapping? The current study examined how the timing of auditory stimuli influenced participants' ability to keep a consistent finger tapping rate. It was hypothesized that participants' finger tapping rates would drift toward the presented auditory stimuli with faster stimuli producing faster tapping rates and vice versa. In Exp. 1, 56 participants tapped to a metronome with their dominant hand and continued this rate throughout the study. Participants were presented with varying auditory stimuli (fast and slow songs) while continuing to tap at the rate of the original metronome. In Exp. 2, 42 participants followed the same methodology, but also engaged in a secondary task in which they listened for errors in the auditory stimuli. Participants' inter tap intervals (ITIs) were recorded and analyzed to determine if they would change their ITIs to match the rates of the auditory stimuli. Results from Exp. 1 indicated that the rate of the auditory stimuli significantly influenced participants' ITIs, with faster tapping in the fast condition compared to the slow condition. Exp. 2 mirrored these results, but with a stronger difference between the ITIs within fast and slow conditions. Overall, results indicate that participants' tapping behaviors are influenced by auditory stimuli. The present results have implications for injury rehabilitation and therapy treatments.

*Keywords: music, fine motor movements, finger tapping*

### The Effect of Music Tempo on Physical Activity

Whether we are walking down the street or watching a movie, music surrounds us. Sometimes people notice the music and actively respond through dancing, while others passively respond by drumming their hands on a table. In short, music has the ability to compel us to move (Chemin, Mouraux, & Nozaradan, 2014; Wittwer, Webster, & Hill, 2013). Movement encompasses a wide variety of activities such as walking, dancing, running, and finger tapping (Repp & Su, 2013). Previous research has indicated that music tempo influences body performance and movement (Chtourou, Jarraya, Aloui, Hammouda, & Souissi, 2012; Shojaei & Sangsari, 2010). Specifically, Wittwer et al. (2013) found that when music or some other auditory stimuli with a steady beat is played, participants are able to accurately match the beat through activities like walking. This suggests that people are influenced by music despite their natural rate tendencies. However, Burger, Thompson, Luck, Saarikallio, and Toiviainen (2013) disputed this claim. They instructed participants to “move” to 30 pieces of popular music “in a way that felt natural” and recorded their movements with an eight-camera optical motion capture system (Burger et al., 2013). Their results showed that the popular music presented did not significantly influence the movements of the participants, which could be because popular music might evoke emotional responses in participants that distract them from their movement. However, when using the same methodology and stimuli to explore how people move to music, results indicated that music does influence movement, where participants could synchronize (Burger, Thompson, Luck, Saarikallio, & Toiviainen, 2014). Their results specifically indicated that participants synchronize better with superior-inferior movements (e.g. bouncing up and down while standing) compared to mediolateral movements (e.g. swaying back and forth with

one's hips while standing); thus, suggesting a complex relationship between the two types of movement and the music.

### **Music and Gross Motor Activities**

Researchers often distinguish between gross and fine motor activities, with gross motor activities including hopping on one foot, and fine motor activities including drawing a person (Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010). A common example of a gross motor activity is a person's gait, which includes speed, stride length, fluency, and balance when walking. Wittwer et al. (2013) found that music influenced the gait speed of their participants, but not their gait variability. This suggests that music can influence their overall speed, but not the specific time between one step and the next.

Music can also influence a person's performance in sports. Often, at sporting events, teams play warm-up music. While this is entertaining for those in the crowd, and it may distract the players from their nerves, it also has some positive effects supported by literature. For example, Shojaei and Sangsari (2010) found that the music played had a positive effect on basketball players' performance. Participants were examined in all three counterbalanced conditions: control (no music during warmup), fast music during warmup, and slow music during warmup. The players were evaluated based on their performance, which consisted of their arousal via heart rate along with additional measures. Shojaei and Sangsari (2010) found that music increased arousal and improved performance with faster music having significantly better playing performance compared to slower music. Furthermore, music impacts running cadence (Van Dyck et al., 2015). Van Dyck et al. (2015) had 14 recreational runners, with the majority of the runners having a musical background, complete a mile 12 different times. On the first lap, participants were instructed to run at their own pace. The second lap had musical accompaniment

that matched the participants' rate of the first lap. The final two laps were counterbalanced in which the participants received music that was faster and slower than the second lap's rate. Their results indicated that running cadence is influenced by music, where faster music increased running cadence and slower music decreased it. In addition, Van Dyck et al. (2015) suggests that music will have a positive effect on a person's ability to perform a physical activity in the moment, but also helps their treatment if they get injured. For example, if runners experience an injury that prevents them from running for a while (e.g. torn ACL), they become timid during recovery and therapy. Their confidence in their ability to perform affects their cadence. By presenting music, therapists are able to influence their patients to actually increase their cadence rate while distracting them with the cognitive load of music.

Those with movement disorders like Parkinson's Disease (PD) also benefit from the effects of music. PD is a progressive neurological movement disorder that tends to present itself in older adults (de Dreu, van der Wilk, Poppe, Kwakkel, & van Wegen, 2012). A typical PD gait consists of a wide and unsteady base with balance problems (del Olmo & Cudeiro, 2005). As the disease progresses, gait, as well as other movements, are affected, often slowing individuals down and increasing their falls (del Olmo & Cudeiro, 2005). However, a meta-analysis by de Dreu et al. (2012) found that music-based movement-therapy improved the gait and gait-related activities of those with PD. Similarly, therapy with rhythmic sounds led to improved gait variability in those with PD (del Olmo & Cudeiro, 2005). These studies suggest a real world application as the lives and safety of those with PD can actually improve with therapy that includes music.

### **Music and Fine Motor Activities**

Researchers often categorize fine motor activities with specific tasks like using building blocks and drawing (Grissmer et al., 2010). Often, this includes activities with the hands and fingers such as gripping, pinching, and tapping (Repp & Su, 2013). Previous literature suggests that when individuals are presented with auditory stimuli and instructed to tap their fingers at the same rate of the stimuli, their rate will synchronize with the stimuli (Hurley, Martens, & Janata, 2014). Furthermore, people's body movements are a visual representation of how a person specifically processes the auditory rhythm (Chemin et al., 2014). Work by Peckel, Pozzo, and Bigand (2014) further supports this notion. Specifically, they had participants perform various oscillatory movements (e.g. moving your arm in a circle, finger tapping) in silence. Then participants continued their movement while listening to music that increased in beats per minute from 60 to 120. Despite not being instructed to do so, they found that participants synchronized with the music playing, and furthermore were influenced into a specific rate. Peckel et al. (2014) suggests that the rhythm of the music is processed and expressed via motor activities.

### **Cognitive Aspects of Music and Movement**

Music has the ability to induce movement; but, what neurocognitive factors play a role in this phenomenon? The brain regions involved in motor control are the basal ganglia, supplementary motor area, and premotor cortex (Hurley et al., 2014). Other research has indicated that the cerebellum is also involved in motor control (del Olmo, Cheeran, Koch, & Rothwell, 2007). Furthermore, Hurley et al. (2014) states that these structures are sensitive to auditory rhythms. This supports the findings of previous literature where gross and fine motor movements are influenced by the auditory or musical stimuli the individual hears. Neuroimaging studies have also shown that motor areas are activated when listening to music, suggesting a strong connection between auditory and motor systems (Schaefer, 2014). Previous literature has

also focused on the idea of entrainment (Burger et al., 2014). When referring to humans, entrainment suggests that individuals can coordinate their rhythm with another human or external stimulus, further supporting the notion that music influences movement (Burger et al., 2014).

### **The Present Study**

Literature has shown that music influences the way that we move (de Dreu et al., 2012; Hurley et al., 2014; Repp & Su, 2013). However, little research has explored whether or not movements can be influenced by music tempo without explicitly instructing participants to “move with the music” or “match the beat.” The present study aims to determine if music tempo will significantly influence fine motor movements without explicitly informing the participants to “match the beat” of the music stimuli. In Experiment 1, participants synchronized their finger tapping with an external stimulus and were instructed to keep that rate even as the auditory stimuli changed throughout the experiment. Experiment 2 is a replica of Experiment 1, but included a secondary task to ensure that participants were paying attention to the external stimuli. Across both experiments, it was hypothesized that participants would be influenced by the rate of the external stimuli and would change their movement as a result. For example, if presented with a slow song, their movement would be slower compared to their movement if they were presented with a fast song.

## **Experiment 1**

### **Method**

**Participants.** 72 college students from a Midwestern university participated in this study for course credit. 12 participants were excluded because they did not follow the directions. Additionally, 4 participants were excluded because they reported hearing difficulties. A total of 56 participants were included in the final analyses. There were 18 men (age: 18.61 years) and 38

women (age: 18.58 years). Furthermore, there were 29 participants with no music training and 27 participants with some private music lessons (average amount of private music lessons = 1.67 years). The present study was approved by the university's Institutional Review Board.

**Materials.** Using DirectRT software, participants received auditory stimuli through Kensington headphones at a comfortable volume and responded by continuously tapping the space bar. The auditory stimuli consisted of three parts: a metronome, “Kitty Wells”, and “Birdies’ Ball”. “Kitty Wells” and “Birdies’ Ball” were adapted from American folksongs and were played with piano timbre for approximately 60 seconds in the slow condition and 40 seconds in the fast condition (Peters, 1977) (see Figures 1 and 2). The metronome was presented for approximately 30 seconds at 90 beats per minute (bpm), which is 667 milliseconds (ms) between beats. Both “Kitty Wells” and “Birdies’ Ball” were presented at both 70 bpm (857 ms) and 110 bpm (545 ms). This was done so the auditory stimuli were not exactly half or double the rate of the metronome, ensuring that the stimuli did not have the same underlying pulse. Participants were also given a questionnaire to determine if they recognized the American folksongs and the purpose of the study (see Appendix A).

**Design and Procedure.** The study was a within-subjects design that consisted of two blocks separated by the completion of a basic demographic and music history form (see Appendix B). In block one, participants first heard the metronome. In order to proceed to the next stimulus, participants had to tap the space bar to the rate of the metronome for a total of 25 taps (or responses). This was done to establish a consistent rhythmic tap. Following the metronome, participants continued tapping while they heard silence in their headphones for a total of 15 responses. The silence was used to determine the consistency of the participants’ inter tap intervals (ITIs). Then, participants heard either “Kitty Wells” or “Birdies’ Ball” for a total of



20 responses, followed once again by silence for another 15 responses. Block two consisted of the same design, except participants received the opposite stimuli and rate of “Kitty Wells” or “Birdies’ Ball”.

The independent variable was the rate of the musical excerpt. The dependent variable was the participants’ ITIs. Each block was counterbalanced. There were four different orders based on the rate of the music, and which excerpt (“Kitty Wells” or “Birdies’ Ball”) came first. (See Figure 3 for a flow chart of the design.)

Prior to the start of the study, participants were instructed that they would hear various sounds through their headphones. Their task was to continue to tap at the rate of the metronome throughout the entire study, even if silence or other music followed. Participants then completed one of four counterbalanced orders, were debriefed, and given their course credit.

## **Results**

After analyzing what each participant thought the purpose of the study was, all 56 participants were included in the following analyses. Common responses including “The purpose of the study was to see how well college students can multitask” and “To see how well I can do one thing while doing another thing.”

Average ITIs were computed for each part of the study: metronome, silence, fast melody, and slow melody. These averages were computed across 20 button presses for the metronome, 15 button presses for the silence, and 20 button presses for the musical stimuli respectively. The first five button presses were removed from the metronome computations since participants were adjusting to the task. See Table 1A for a list of average ITIs.

A repeated measures ANOVA was then computed to determine the ITI differences between the fast and slow melody. The ITIs significantly differed between the slow and fast

melody, where ITIs were faster during the fast melody ( $M = 605.15$  ms) compared to the slow melody ( $M = 626.07$  ms) ( $F(1, 55) = 10.92, p = 0.002, \eta_p^2 = 0.166$ ). (See Figure 4.)

A one sample  $t$ -test was used to determine how well participants matched the rate of the metronome while listening to the metronome in each block. The rate of the participants was significantly faster than the metronome indicating that the initial metronome might be too slow ( $t(55) = -14.41, p < 0.0001$ ). Furthermore, a paired-samples  $t$ -test showed a significant difference between the tapping rate during the fast song and the tapping rate during the metronome versus the slow song and the metronome difference ( $t(55) = 3.42, p = 0.001$ ), with a larger difference between the fast song and metronome.

To determine if the order of the musical stimuli had an effect on participants' ITIs, a 2(Song order: "Birdies' Ball" vs. "Kitty Wells") x 2(Rate presented first: Fast vs. Slow) ANOVA was computed. The order of the songs presented had no significant effects ( $F(1, 52) = 0.021, p = 0.885, \eta_p^2 = 0.000$ ). Furthermore, the order of the rates that were presented had no significant effects ( $F(1, 52) = 0.057, p = 0.812, \eta_p^2 = 0.001$ ).

An ANOVA was also computed to determine if musical background had an effect on participants' ITIs. Musical background was broken into two categories of musicians and non-musicians, where musicians had 2 or more years of experience and an average of 1.67 years of private music lessons. Analyses concluded that musicians did not significantly differ from non-musicians in ITIs ( $F(1, 54) = 0.087, p = 0.769, \eta_p^2 = 0.002$ ).

## Discussion

The results of the present study supported the hypothesis that participants would be influenced by the rate of the external stimuli and change their movements accordingly. It was found that participants significantly changed their ITIs. When they were presented with the slow

musical excerpt their ITIs were slower compared to when they were presented the fast musical excerpt. However, because Experiment 1 did not encourage participants to actively listen to the musical excerpt, Experiment 2 was conducted.

## **Experiment 2**

### **Method**

**Participants.** 66 college students from a Midwestern university participated in this study for course credit. 24 participants were excluded from our study because they did not follow the directions. In total, 42 participants with normal hearing were included in final analyses. There were 18 men (age: 18.44 years) and 24 women (age: 18.33 years). Furthermore, there were 29 participants with no music training and 13 participants with some private music lessons (average amount of private music lessons = 2.38 years). The present study was approved by the university's Institutional Review Board.

**Materials.** The materials in experiment 2 were the same as Experiment 1. However, there were minor changes to the musical excerpts of “Kitty Wells” and “Birdies’ Ball”. Specifically, 6 errors were added to each excerpt. Errors were characterized as a double note played on the keyboard in the wrong key of the song (see Figures 5 and 6). As in Experiment 1, the songs were approximately 60 seconds in the slow condition and 40 seconds in the fast condition. Participants also received a modified version of the questionnaire from experiment 1 which also asked participants how many errors they heard in each block of the study (see Appendix C).

**Design and Procedure.** Experiment 2 had the same methodology as Experiment 1 with a couple of minor changes. First, participants were instructed to count the errors that they would hear throughout the musical excerpts because they would be asked about them later in the study.

Second, participants received an updated music and demographic form between blocks 1 and 2 that also included the question “How many errors did you hear?” (see Appendix D).

## Results

After determining what each participant thought the purpose of the study was, all 42 participants were included in the following analyses. Commonly reported purpose statements were “To see how well students can focus” and “To see how well I can multitask.”

For the metronome, silence, fast melody, and slow melody, average ITIs were computed. The averages were computed across 20 button presses for the metronome, 15 button presses for the silence, and 20 button presses for the melodies. As in Experiment 1, the first 5 button presses were removed from the metronome averages as participants were still adjusting to the task. See Table 1B for a list of average ITIs.

To determine the difference between ITIs during the fast and slow melodies, a repeated measures ANOVA was conducted. Participants’ ITIs were significantly different from one another ( $F(1, 41) = 9.29, p = 0.004, \eta_p^2 = 0.185$ ). Specifically, when participants were presented with the fast melody their ITIs were faster ( $M = 610.08$  ms) compared to when they were presented with the slow melody ( $M = 676.21$  ms). (See Figure 7.)

A one sample  $t$ -test was used to determine how well participants were able to continue the rate of the metronome throughout the experiment. Participants’ rate throughout the study was significantly faster than the metronome, mirroring the results of Experiment 1 ( $t(41) = -4.60, p < 0.0001$ ). In addition, a paired-samples  $t$ -test showed a significant difference between the tapping rate during the fast song and the tapping rate during the metronome versus the slow song and metronome difference mirroring the results of Experiment 1 ( $t(55) = 3.42, p = 0.001$ ), with a larger difference between the fast song and metronome.

Additional analyses were conducted to determine if there were order effects. First, an ANOVA confirmed that the order of the songs presented had no significant effects ( $F(1, 38) = 0.495, p = 0.486, \eta_p^2 = 0.013$ ). Furthermore, the order of the rates presented had no significant effects ( $F(1, 38) = 2.73, p = 0.11, \eta_p^2 = 0.067$ ).

In order to determine if musical background had an effect on participants' ITIs, an ANOVA was conducted. Musical background was broken into two categories of musician and non-musician. Musicians were characterized by having 2 or more years of musical experience and an average of 2.38 years of private music lessons. Final analyses concluded that musicians did not significantly differ from non-musicians in their average ITIs across the melodies ( $F(1, 40) = 0.237, p = 0.629, \eta_p^2 = 0.006$ ).

A 2 x 2 repeated measures ANOVA was also conducted to determine if Experiment 1 and Experiment 2 results significantly differed, with experiment as the between subjects factor and rate condition as the within subjects factor. Analyses concluded that Experiments 1 and 2 significantly differed from one another, with Experiment 2 having a more exaggerated difference between ITIs under fast and slow conditions ( $F(1, 96) = 5.04, p = 0.027, \eta_p^2 = 0.050$ ).

## **Discussion**

The results of Experiment 2 mirrored the results of Experiment 1 with a more exaggerated effect, which also supported the present study's hypothesis that external stimuli would influence the movement of the participants. Specifically, when participants received the slow song their ITI was slower compared to when presented with a fast song.

### **General Discussion**

The present study's results suggest that music tempo influences fine motor tasks. This is noteworthy as participants were not instructed to change their rate of tapping. In fact, they were

instructed to continue to match a tempo presented by a metronome. Specifically, participants' ITI decreased when presented with the fast melody and increased when presented with the slow melody. The results of Experiment 2 mirrored those of Experiment 1, but with a more exaggerated effect in how much participants were influenced to change their tapping rate by the musical pieces.

But, what exactly caused participants to have this response to the musical pieces? First, the present study's results might have occurred because of mirror neurons. Mirror neurons are neurons in the brain that allow people to connect meaning and attention by adapting a representation of it in their own head (Molnar-Szakacs & Overy, 2006). This suggests that mirror neurons influence the way that people move in response to musical stimuli as the person co-represents the movement and the musical stimuli in their brain (Molnar-Szakacs & Overy, 2006). Furthermore, the present study's results might also be explained with the idea of entrainment. Entrainment is when two or more independent organisms coordinate rhythms (Burger et al., 2014). In humans, entrainment allows people to synchronize their rhythms with other humans or an external musical stimulus (Burger et al., 2014). In the present study, participants may have entrained to each piece, thus, explaining why participants' ITI changed based on what type of rate the musical piece was.

A study by Peckel et al. (2014) further supports the present study's findings. Peckel et al. instructed participants to move at a natural self-pace while the music played, which differed from the present study's explicit instructions to synchronize with a different auditory stimulus. Peckel et al. (2014) also informed participants that the musical stimuli they would hear would be changing in rate and that they should not pay attention to it, which also differed from the present study where no information about the music stimuli was given. Peckel et al. (2014) found that

participants successfully matched their movements with the rate of the music. Furthermore, when participants were presented with various musical rates in succession, their movements continued to match the presented music. The present study supports and extends their work as participants' physical movements changed to match the music tempo without instruction to synchronize with the music.

As mentioned above, Experiment 2 mirrored the results from Experiment 1; however, the results from Experiment 2 were exaggerated as participants were significantly more influenced by the musical pieces. This might have occurred because of the secondary task in Experiment 2 that encouraged participants to actively pay attention to the musical pieces by instructing participants to count the “errors” within them. By providing other musical factors, like “errors” in a song, it increases the listener’s attention (Hurley et al., 2014). As a result, this can exaggerate the effect of the sensorimotor coupling that occurs when auditory stimuli are processed (Hurley et al., 2014); thus, explaining why participants in Experiment 2 were influenced by the musical pieces more than those in Experiment 1. An alternate explanation for the exaggerated results in Experiment 2 is the possibility of an increased cognitive load as the secondary task was implemented to ensure listening; thus, possibly making it more difficult to keep the original beat of the metronome.

While the present study offers insight to the present literature, there are some limitations. For example, some of the current literature does not support the idea that music influences body movement (Burger et al., 2013). However, Burger et al. (2013) differed from the present study by using popular music as the external stimuli, which may have averse emotional effects on individuals if it is not their preferred genre. This may distract participants in a way that undermines the influence of the stimuli (Burger et al., 2013). Furthermore, the present study’s

musician population was not highly trained. Musicians on average had 2.03 years of private lessons across both studies. However, previous studies have classified musicians as those who have had more than 2 years of musical experience (McAdams, Winsberg, Donnadieu, De Soete, & Krimphoff, 1995; Patston & Tippet, 2011). This might explain why the present study found no difference between musician and non-musician ITIs. In addition, the presented metronome rate might have been too slow. Across both experiments, participants were significantly faster than the presented metronome with which they were instructed to synchronize. The rate of the metronome was 667 ms; however, Burger et al. (2014) suggests that people's preferred tapping rate is 500 ms. This could explain why the rates of the participants during the slow songs did not go slower than the rate of the presented metronome. Finally, the present study focuses only on finger tapping, instead of multiple fine motor movement tasks.

The results of the present study suggest that music tempo could have a positive effect on rehabilitation therapy sessions. Specifically, the present study found that participants changed their tapping rate to match the rate of the melody without instructions to do so; thus, suggesting that participants' movement can be influenced without an active decision to change. Those in therapy would benefit from this as music would allow them to blend how well they are completing their exercise (quality) with their overall speed (quantity), all without compromising quality or quantity; therefore, improving their therapy session. This is further supported by previous literature exploring rehabilitation in PD patients, which found that patients' gait was significantly improved in speed and smoothness once they completed music therapy (de Dreu et al., 2012; del Olmo & Cudiero, 2005). Music therapy's ability to subconsciously influence patients' movement essentially allows patients to focus on the quality of their exercise and



recovery, instead of on the difficulties of therapy (e.g. pain, stress, self-image, not improving fast enough, etc.) (Lopes-Silva, Lima-Silva, Bertuzzi, & Silva-Cavalcante, 2015).

The present study provides evidence that music tempo influences fine motor tasks. Furthermore, the study adds to the present literature by offering evidence that the phenomenon of moving to the music requires no instruction. These results could have a large real-world impact on therapy as therapists will be able to instruct patients to perform a task at a specific rate without focusing their attention on the rate, but instead the quality of the task. This further helps patients enjoy their therapy sessions, thus increasing their likelihood to complete their recommendations and attain their highest level of functioning. Future studies should adjust the rate of the metronome to match the client's preferred rate while also exploring if other fine motor tasks would produce the same results. Other studies should also explore the difference between highly skilled musicians (e.g. 4 or more years of experience) and non-musicians on the same task. Furthermore, studies should explore how the brain interacts with music and motor movements to provide a better understanding on how people's movements are influenced by music without instruction to actively synchronize. Finally, this task should be implemented in a rehabilitation therapy setting to offer real-world implications and support.

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Table 1A

*Experiment 1 ITI Averages for Each Part of the Study Across Blocks 1 and 2*

Part	Average ITI (ms)
	<i>M</i> (SD)
Metronome	655.10(8.28)
Silence	637.91(36.15)
Fast Song	605.15(42.89)
Slow Song	626.07(55.76)

Table 1B

*Experiment 2 ITI Averages for Each Part of the Study Across Blocks 1 and 2*

Part	Average ITI (ms)
	<i>M</i> (SD)
Metronome	655.60(19.44)
Silence	649.49(143.27)
Fast Song	610.08(91.42)
Slow Song	676.21(110.69)



Figure 1. Notation for “Kitty Wells”



Figure 2. Notation for "Birdies' Ball"



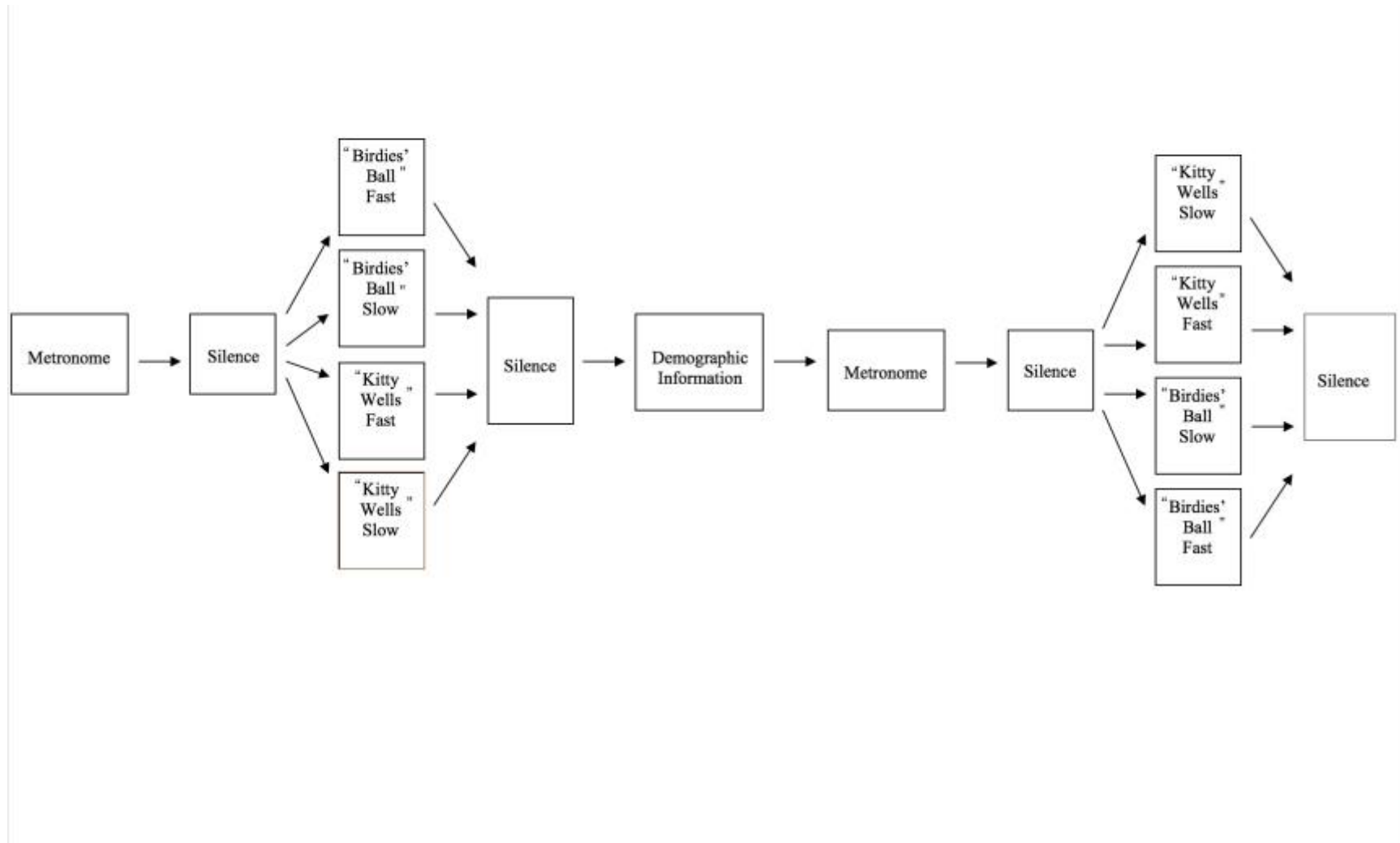
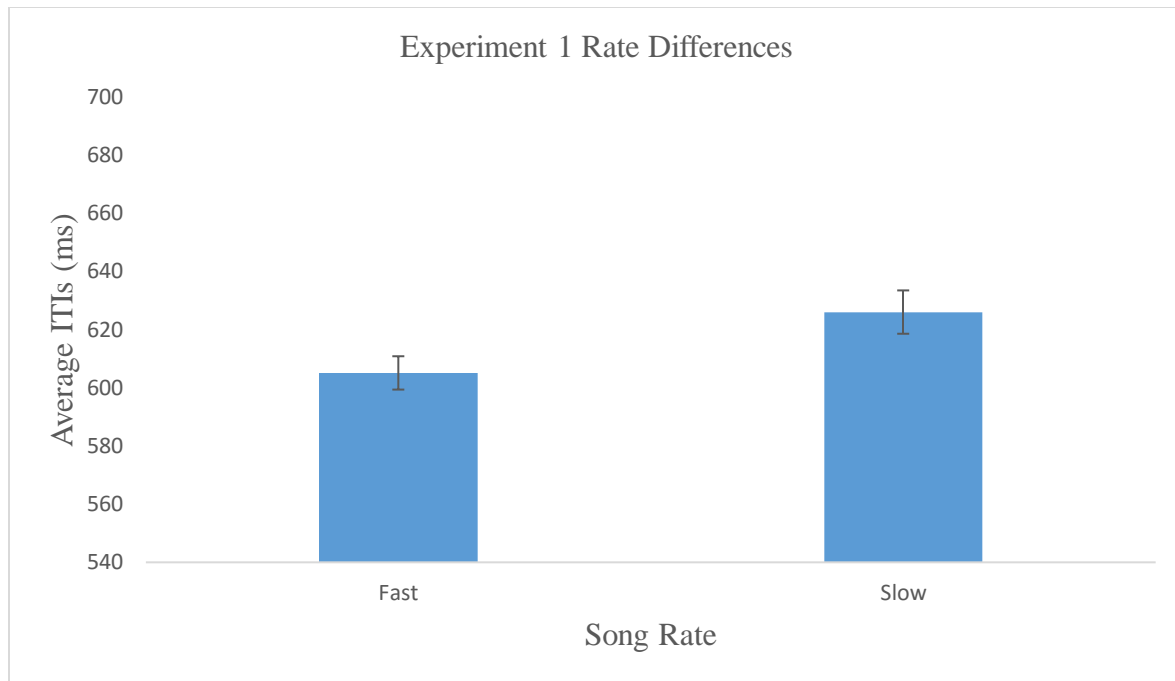


Figure 3. A flow chart of the design of Experiments 1 and 2. Demographic information separates blocks 1 and 2. Metronomes were presented at 90 bpm. Musical excerpts were presented at 70 bpm for slow and 110 bpm for fast.



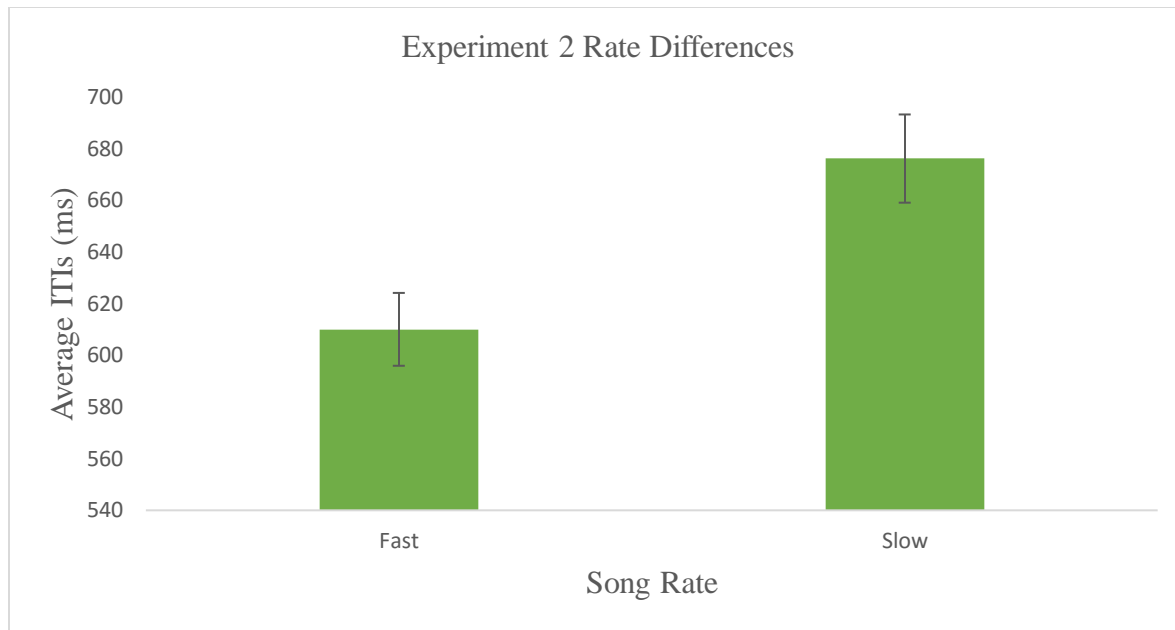
*Figure 4.* Experiment 1 difference in ITIs between fast and slow conditions. There was a significant difference in ITIs (ms), where the fast song rate had faster ITIs compared to the slow song rate,  $p = 0.002$ . Standard errors are represented by the error bars attached to each column.



Figure 5. Notation for “Kitty Wells” with errors



Figure 6. Notation for "Birdies' Ball" with errors



*Figure 7.* Experiment 2 difference in ITIs between fast and slow conditions. There was a significant difference in ITIs (ms), where the fast song rate had faster ITIs compared to the slow song rate,  $p = 0.004$ . Standard errors are represented by the error bars attached to each column.

Appendix A

Experiment 1 Song Recognition and Purpose Questionnaire

Participant number \_\_\_\_\_

Order \_\_\_\_\_

Did you recognize any of the songs you heard today? If so, please write down the title or a few words from the song.

What is the purpose of the study?

## Appendix B

## Experiment 1 Demographic and Music History Form

Participant number \_\_\_\_\_

Order \_\_\_\_\_

## Music and Language Background Form

Please take time to answer the following questions about your music and language background.

1. What is your gender? Male \_\_\_\_\_ Female \_\_\_\_\_

2. What is your age? \_\_\_\_\_

3. What is your race/ethnicity? (*check all that apply*)

\_\_\_\_\_ Black or African American

\_\_\_\_\_ Asian

\_\_\_\_\_ Native Hawaiian or other Pacific Islander

\_\_\_\_\_ White

\_\_\_\_\_ American Indian or Alaska Native/First Nations

\_\_\_\_\_ Hispanic or Latino

\_\_\_\_\_ Other: \_\_\_\_\_

4. What musical instrument(s) do you play, if any? How many years have you been playing each instrument?

5. How many years of private instruction on each instrument have you had?

6. At what age did you start lessons?

7. Do you still play these instruments? If so, which ones and how many hours a week?

8. How often do you take music lessons?

9. When/where do you listen to music? Check all that apply:

car      work      studying      meals      working out      bedtime      other: \_\_\_\_\_

10. Do you teach music lessons, and if so, for how long?

11. Have you taken any ear training classes?

12. Are you right- or left-handed?

13. Do you have any hearing problems?

14. What language(s) was spoken in your home before you were 3 years old?

15. What language(s) do you speak fluently?



Appendix C

Experiment 2 Song Recognition and Purpose Questionnaire

Participant number \_\_\_\_\_

Order \_\_\_\_\_

How many errors did you hear in the second half of the study?

Did you recognize any of the songs you heard today? If so, please write down the title or a few words from the song.

What is the purpose of the study?

Appendix D

Experiment 2 Demographic and Music History Form

Participant number \_\_\_\_\_

Order \_\_\_\_\_

How many errors did you hear?

## Music and Language Background Form

Please take time to answer the following questions about your music and language background.

1. What is your gender? Male \_\_\_\_\_ Female \_\_\_\_\_

2. What is your age? \_\_\_\_\_

3. What is your race/ethnicity? (*check all that apply*)

\_\_\_\_\_ Black or African American

\_\_\_\_\_ Asian

\_\_\_\_\_ Native Hawaiian or other Pacific Islander

\_\_\_\_\_ White

\_\_\_\_\_ American Indian or Alaska Native/First Nations

\_\_\_\_\_ Hispanic or Latino

\_\_\_\_\_ Other: \_\_\_\_\_

4. What musical instrument(s) do you play, if any? How many years have you been playing each instrument?

5. How many years of private instruction on each instrument have you had?

6. At what age did you start lessons?

7. Do you still play these instruments? If so, which ones and how many hours a week?

8. How often do you take music lessons?

9. When/where do you listen to music? Check all that apply:

car      work      studying      meals      working out      bedtime      other: \_\_\_\_\_

10. Do you teach music lessons, and if so, for how long?
11. Have you taken any ear training classes?
12. Are you right- or left-handed?
13. Do you have any hearing problems?
14. What language(s) was spoken in your home before you were 3 years old?
15. What language(s) do you speak fluently?